Summary

This Ph.D. research investigates the design, implementation, and application of Regional Digital Twins (RDTs) for integrated disaster prevention and risk management. RDTs are conceived as dynamic, multi-scale digital representations of territories, capable of supporting decision-making processes by integrating heterogeneous datasets from GIS, BIM, IoT, and remote sensing sources. The study addresses key challenges in the field, including multi-resolution data integration, semantic harmonization between BIM and GIS models, real-time ingestion of environmental and infrastructural sensor data, and the validation of digital simulations through field observations.

A hybrid methodological framework was developed, combining open-source solutions (such as QGIS) and proprietary platforms (ArcGIS Pro and ArcGIS Online), to design scalable and interoperable RDT architectures. Particular attention was given to the modeling of natural hazards, focusing on flood and landslide risks, through the creation of predictive models informed by historical data and live monitoring inputs. The research also contributed to refining workflows for the generation of 3D subsurface models, particularly in the context of environmental remediation projects, with the GeoBIM model developed for the Parco della Salute, Ricerca e Innovazione (PSRI) site serving as a case study.

Furthermore, the project developed a Proof of Concept, *DTforVR*, exploring the use of Virtual Reality to visualize and communicate the dynamic behaviors of territorial digital twins. This effort highlighted the potential of immersive environments for enhancing public awareness, stakeholder engagement, and training activities related to territorial risk management.

The research introduces a modular and replicable approach for RDT implementation, proposing a methodology that spans from static spatial data processing to dynamic data integration and predictive scenario simulation. Special emphasis was placed on the need for model validation protocols, addressing uncertainties stemming from heterogeneous data sources and evolving territorial conditions.

In conclusion, the thesis demonstrates that Regional Digital Twins can significantly enhance the resilience of territories by enabling a proactive, data-driven management of natural risks. The proposed methodologies and developed tools lay the groundwork for future operational applications of RDTs within regional governance systems, contributing to a paradigm shift from static territorial representations to dynamic, process-based models capable of supporting sustainable planning and risk mitigation strategies.